

IV Data Evaluation

4.1 Neutron Data Evaluation for General Purpose File

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Recent years, the complete neutron data evaluation has been done for CENDL-2 (Chinese Evaluation Nuclear Data Library, Second Version) in China. The incident neutron energy range is from 10^{-3} eV to 20 MeV and the data type contains MF 1 to MF 5 (in ENDF/B-4 format).

A Nuclear Cross Section Evaluation System (NCSSES) has been used either at Nuclear Data Center or at other units of the cooperation network to process EXFOR experimental data, including the data retrieve, format conversion, plotting and comparing, curve fitting, joint adjusting, output in ENDF/B format and so on.

The programs AUJP and MUP-2 have been used for theoretical calculation. The former is a optical model calculation program with parameter auto-adjusting, and the latter is a statistical calculation program, including Hauser-Feshbach and pre-equilibrium theory.

So far the evaluations have been finished for nuclides P, S, Ca, Ti, Sb, Mn, Co, Pb, W, Al, Ag, Cd, In and are underway for nuclides K, Fe, ^{235}U , ^{238}U and ^{239}Pu , ^{240}Pu .

In addition to the evaluations for CENDL-2, also some evaluations have been done for international cooperation, including ^{107}Ag , ^{109}Ag , ^{184}Ag (for JENDL-3), ^{241}Am , ^{249}Bk , ^{250}Cf (for ENDF/B-6). The evaluations for nuclides O, F (for ENDF/B-6) and the review for nuclides ^7Li , ^9Be , ^{235}U , ^{238}U , ^{239}Pu , ^{240}Pu (for ENDF/B-6) are underway.

4.2 Evaluation of Complete Neutron Data for Natural Tungsten

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1. Total cross section

Since 1975, most of the total cross section have been measured with white light source and TOF method. There are structures in the energy range below 10 keV.

In the energy range from 1.0×10^{-4} to 0.1 eV and 0.1 eV to 100 keV, the evaluated data of ENDL/84 and UNC-5099 are adopted respectively. In the energy range 100 keV ~ 20 MeV, the experimental data fitted with spline function^[4] are taken as recommended one. In the energy range $10^{-5} \sim 10^{-4}$ eV, the data are extrapolated one.

2. Capture cross section

New measured data of Xiang (86)^[5], Macklin (83)^[6], Poenitz (82)^[7], Joly (81)^[8], Fricke (70)^[9] and Budnar (79)^[10] are available in the energy range from 100 keV to 4 MeV. These make the evaluated data considerably improved (Fig. 1).

3. (n, 2n), (n, 3n) reaction cross section

For (n, 2n) reaction, the new data were measured by Frechaut (80)^[11] and Veerer (81)^[12] in the energy range from 7.9 to 14.8 MeV and 14.7 to 20 MeV respectively. For (n, 3n) reaction, new data were measured by Veerer (81)^[12] in the energy range from 14.7 to 20 MeV. Based on these new data, the evaluated data are greatly improved (Fig. 2).

4. Inelastic scattering cross section

The cross sections of inelastic scattering to 20 discrete levels are calculated with MUP2 code, but they are normalized to the experimental data of Lister (62)^[13] and Guenther (82)^[14] in the energy range below 3.5 MeV (Fig. 3).

5. Other reactions

For other reactions, there are also some new measured data, Begum (81)^[15]

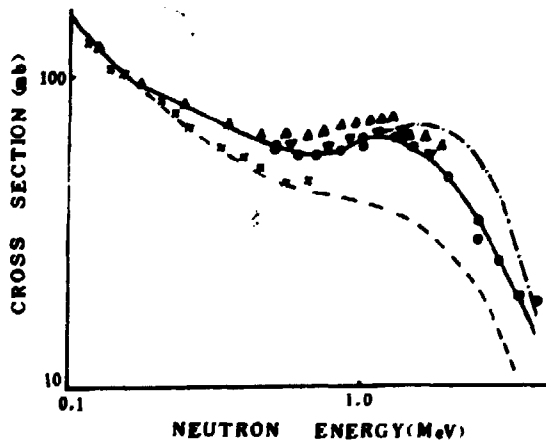


Fig.1 Evaluated capture cross section is compared to recent experimental data

- | | |
|------------------------|-------------------------------|
| ▽ XIANG ZHENGYU (1986) | × FRICKE (1970) |
| △ MACKLIN (1983) | — THIS WORK |
| ○ POENITZ (1982) | - - - THEORETICAL CALCULATION |
| ● JOLY (1980) | - · - LAST TIME (1978) |

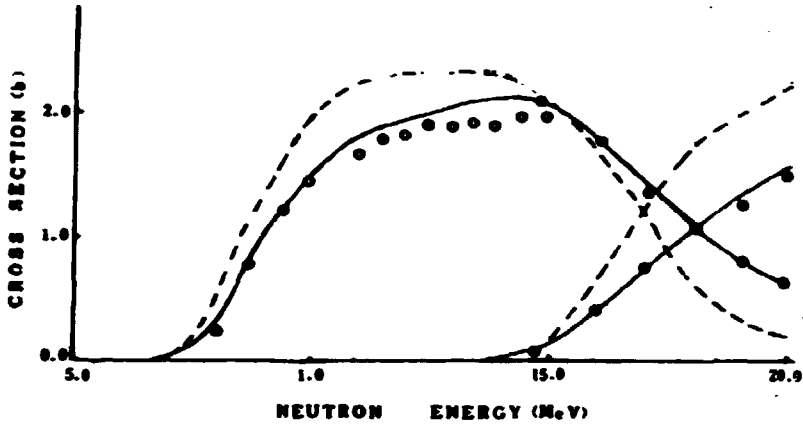


Fig.2 Evaluated (n,2n) and (n,3n) cross section are compared to recent experimental data.

○ OFREHAUT(1980) ● VEESER(1981)
 — ENDF/B-V — THIS WORK

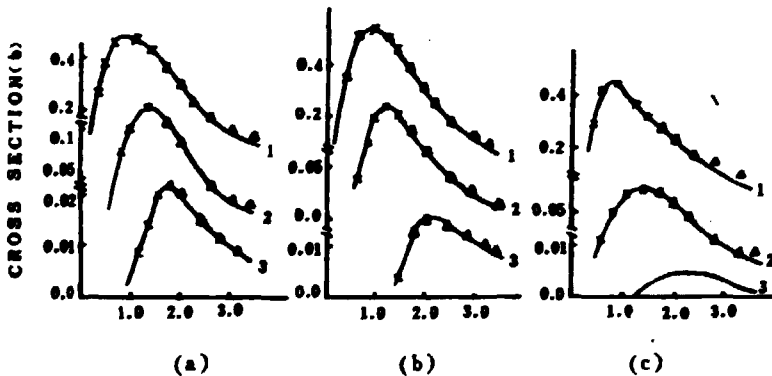


Fig.3 Evaluated inelastic excitation cross sections are compared to experimental data.

×	LISTER(1967)	△	GUENTHER(1982)	—	THIS WORK
a.	1. 0.1091MeV(2 ⁺)	b.	1. 0.1112MeV(2 ⁺)	c.	1. 0.1223MeV(2 ⁺)
	2. 0.3294MeV(4 ⁺)		2. 0.3641MeV(4 ⁺)		2. 0.3985MeV(4 ⁺)
	3. 0.6805MeV(6 ⁺)		3. 0.7483MeV(6 ⁺)		3. 0.8085MeV(6 ⁺)
	W-182		W-184		W-186

for angular distribution of elastic scattering (Fig. 4), Pai (80)⁽¹⁶⁾ for non-elastic and Qaim (75, 82)⁽¹⁷⁾ for charged particle. For (n,p) and (n,n'p) reactions, the theoretical curves calculated by using MUP2 code are normalized to Qaim's data at 14.7 MeV.

6. Theoretical calculation

For supplement, the data for tungsten are calculated with programs AUJP⁽¹⁾ based on optical model and MUP2⁽¹⁾ based on optical model, H-F statistical

model and pre-equilibrium evaporation model in the energy range from 1 keV to 20 MeV. The comparison between calculated and measured data is given in the table 1.

Table 1. The comparison between calculated and measured data

E_0 (MeV)	σ_{tot}			$\sigma_{n,n}$			$\sigma_{p,n}$		
	theo.	eval.	% Δ	theo.	eval.	% Δ	theo.	eval.	% Δ
1.8	7.02	7.00	0.3	4.68	4.36	7.47	2.33	2.64	11.5
2.2	6.96	7.10	1.3	4.53	4.43	2.36	2.43	2.67	8.97
2.6	6.86	7.11	3.5	4.39	4.44	1.46	2.48	2.67	6.93
3.0	6.72	7.00	3.97	4.21	4.35	3.18	2.51	2.65	5.26
3.6	6.46	6.74	4.1	3.84	4.13	4.6	2.52	2.61	3.30
4.0	6.29	6.49	3.07	3.76	3.90	3.6	2.53	3.59	2.28
4.82	5.90	6.01	1.8	3.34	3.46	3.36	2.55	2.54	0.31
6.509	5.34	5.34	0.06	2.78	2.82	1.24	2.55	2.52	1.53
7.452	5.17	5.15	0.32	2.62	2.64	0.69	2.54	2.50	1.38
8.56	5.04	5.05	0.2	2.52	2.56	1.78	2.52	2.48	1.42
10.0	5.02	5.09	1.49	2.52	2.63	4.16	2.49	2.46	1.36
12.0	5.14	5.21	1.28	2.67	2.77	3.45	2.46	2.44	0.96
14.1	5.30	5.35	0.85	2.89	2.95	2.19	2.41	2.39	0.75
16.0	5.40	5.42	0.27	3.65	3.66	0.41	2.35	2.36	0.1
18.0	5.46	5.38	1.57	3.15	3.06	3.14	2.30	2.32	0.49
20.0	5.52	5.30	4.12	3.23	3.02	6.86	2.29	2.28	0.49

$$\Delta = \frac{|\text{theo.} - \text{meas.}|}{\text{meas.}} \times 100$$

The main parameters used are as follows.

(1) Optical potential parameters (MeV or Fermi) ;

$$\begin{aligned} A_r &= A_{s0} = 0.322 & V_0 &= 47.655 \\ A_s &= A_v = 0.681 & V_1 &= -0.237 \\ X_r &= X_{s0} = 1.307 & V_2 &= 0.011 \\ X_s &= X_v = 1.265 & V_3 &= -24.0 \\ X_c &= 1.25 & V_4 &= 0.0 \\ U_0 &= -0.187 & W_0 &= 8.806 \\ U_1 &= 0.032 & W_1 &= -0.111 \\ V_{s0} &= 6.2 & W_2 &= 0.0 \end{aligned}$$

(2) Level density parameters is given in Table2.

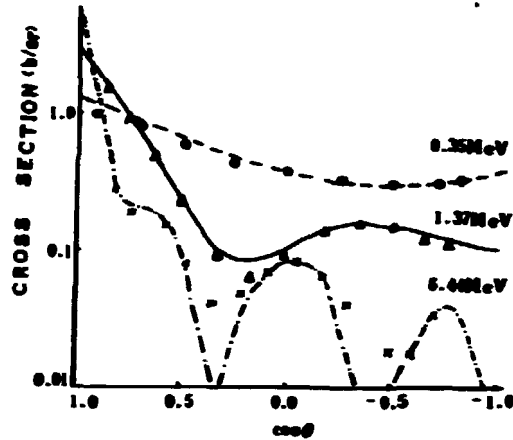


Fig.4 Comparison of the evaluated angular distributions for elastic scattering and experimental data.

○SMITH (1960) △TSUKADA (1969) ×KINNEY (1973)
 ———THIS WORK
 - - - - -THIS WORK

Table 2 Level density parameters*

P (z)	P (n)	S (z)	S (n)	P (z)	P (n)	S (z)	S (n)
W-182				W-183			
0.60	0.0	-7.3	6.94	0.60	0.75	-7.3	6.55
0.0	0.75	-7.24	6.96	0.0	0.0	-7.24	6.94
0.60	0.0	-7.45	7.15	0.60	0.75	-7.45	6.96
0.0	0.5	-7.9	7.35	0.0	0.0	-7.9	7.15
0.60	0.0	-8.13	7.4	0.60	0.5	-8.13	7.35
W-184				W-186			
0.60	0.0	-7.3	6.72	0.60	0.0	-7.30	6.69
0.0	0.75	-7.24	6.55	0.0	0.86	-7.24	6.49
0.60	0.0	-7.45	6.94	0.60	0.0	-7.45	6.72
0.0	0.75	-7.9	6.96	0.0	0.75	-7.9	6.55
0.60	0.0	-8.13	7.15	0.60	0.0	-8.13	6.94

* The level density formula of Ref. [18] are used.

7. Concluding remarks

This evaluation is for CENDL-2 and based on CENDL-1¹¹. Due to the new experimental data have been available for recent years, the evaluated data have been considerably improved especially for cross sections of (n,2n),

($n, 3n$), (n, γ) reactions and inelastic scattering to some discrete levels.

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4.3 Neutron Data Evaluations of ^{31}P , S and K

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Complete neutron data evaluations have been finished for nuclides ^{31}P , S and K in the incident neutron energy range from 10^{-5} eV to 20 MeV. Measured data up to 1985 for ^{31}P and S, 1988 for K are collected and fitted with spline function after careful analyses. The theoretical calculations are performed by Code MUP-2 with neutron optical potential parameter adjusting by means of Code AUJP. The complete evaluated data are checked with codes SUM4, CHK4, FIZCON, PSYCHE and submitted to Chinese Evaluated Nuclear Data Library,